SH
223
C212
FISH

574.0671

BULLETIN of the BIOLOGICAL BOARD of CANADA. No. 1.

Histories of New Food Fishes

I. THE CANADIAN PLAICE

BY

A. G. HUNTSMAN,
Biologist to the Biological Board of Canada

Smithsonian Institution
JUN 8 - 1918
242811

Price - - 15 cents

574.0671

MARCH, 1918

UNIVERSITY OF TORONTO PRESS
TORONTO

SHOUT
SHARE
IT

We present herewith the first of what, it is hoped, will prove to be a long and important series of bulletins dealing with our food-fishes. There has been a steadily increasing need for a simple and accurate presentation of the facts that have a bearing upon each one of the various problems presented by our fisheries. The many scientific reports which represent great advances in our knowledge, of necessity contain too many technical details for the ordinary reader, are usually too limited in scope to show the proper relation of the new facts to questions of economic importance, and for these reasons do not fill this need. The intention is to present in simple form to those directly interested in the fisheries the principal facts which they should know in order to make the most of the fishery resources we possess, and these bulletins should prove of use not only for present need but also for future reference.

THE BIOLOGICAL BOARD OF CANADA.

FIG. 1.—Plaice seven inches long from the Bay of Islands, Newfoundland.

BULLETIN of the BIOLOGICAL BOARD of CANADA. No. 1.

Smithsonian Institution
JUN 8 - 1918
National Museum

Histories of New Food Fishes

I. THE CANADIAN PLAICE

BY

A. G. HUNTSMAN,
Biologist to the Biological Board of Canada

Price - - 15 cents

MARCH, 1918

UNIVERSITY OF TORONTO PRESS
TORONTO

THE BIOLOGICAL BOARD OF CANADA.

PROFESSOR E. E. PRINCE.....*Chairman.*

PROFESSOR A. B. MACALLUM.....*Secretary-Treasurer.*

INTRODUCTION.

FOR two reasons there is great need for a rapid expansion of our fishery industry. One of these is the necessity of making the most of every available food stuff owing to the present world shortage. On the other hand the increased utilization of every resource is an essential for the maintenance of our financial credit and the payment of our national debt. Among our resources our fisheries are of great importance. It is frequently stated that we have the greatest fisheries in the world, but however true this may be as regards natural endowment, it is not true of the use that we have made of them, and if we fail to make proper use of our fisheries our heritage will pass to others. A large fishing area lies close at hand along our eastern coast, but the greater part of it is not within our territorial waters and is therefore open to the world. If the proper enterprise is shown in continuing to develop this fishing area, we should be able to compete successfully with other nations for its control because of our fortunate geographic position. Improvements in the methods of handling and transporting the fish are however constantly nullifying the advantages we possess in our proximity to these rich waters, so that vigorous expansion and the use of the most business-like and economical methods are necessary if we are not to lose this fishery.

Foremost among the points to be attacked in this expansion is our failure to make proper use of certain kinds of fish that are obtainable in large quantities or that are taken as by-products in other fisheries and discarded. We purpose furnishing a series of accounts of unutilized fishes in order to show what kinds are available and to point the way to their utilization. In this series it is intended to present in simple form the results of our special investigations, the full reports of which will appear elsewhere.

The chief questions that we shall attempt to answer in these accounts are the following.

What is the most suitable name for the fish?
How can it be most easily recognized?
Where is it to be found?
In what quantity can it be obtained?

How can it best be caught?
In what form should it be marketed?
What size does it attain?
What are its habits?
What does it eat?
How rapidly does it grow?

Although it is quite obvious that these cannot be answered completely, it is hoped that sufficient information will be given to form a proper foundation for the development of the fishery and for its future conservation.

Knowledge is power and the successful business man considers every aspect of the situation from the raw material to the marketing of the finished product before he takes up a new line. Since, unfortunately, knowledge of our fishes is largely lacking even among those engaged in the trade, it is of much practical importance to present knowledge concerning any new line that it is proposed to introduce. We believe that the Canadian Plaice deserves to be one of our more important food fishes, and is a line that should be pushed strongly, so we give the available facts concerning it, which show just how valuable it should be to us if properly handled.

No knowledge is complete and it cannot be claimed that we have answered all the important questions concerning this fish, but we believe that we are able to present so clear and accurate a picture of its life that it will be quite evident what measures should be adopted for its full utilization and proper conservation.

Peculiar difficulties surround an investigation of the life habits of such a fish, seeing that one cannot observe it in its home at any stage in its life history. Although its eggs float near the surface they are so transparent as to be seen only when taken from the water, and the young fry, which also are transparent, have the curious habit of coming near the surface only at night. On the other hand the old fish live on the bottom in water more than a hundred feet in depth and so cannot be seen until they are caught and brought up to the surface. Since direct observation is impracticable, we have to rely wholly upon indirect methods of obtaining information. These scientific methods evolved during many years by a host of investigators have made it possible to give such a complete account as the present one of the life of this fish after having had only a single season for its study.

NAME.

The fish that we are considering is known scientifically by the Latin name of *Hippoglossoides platessoides*, which on translation into English is the 'halibut-like plaice-like' fish, for *Hippoglossus* is the name of the halibut, *Platessa* that of the plaice, and the ending -oides means likeness. The first part of the name is significant, because our plaice is more nearly related to the halibut than to any other of our fishes. The last part shows that Fabricius, the man who was the first to name it and describe it from specimens he obtained in Greenland, saw that it resembled the original plaice, which is found only in European waters.

The common names that have been used for this fish are legion and none find very general acceptance. The small European variety (var. *limandoides*) is usually known by the following names in the several countries listed. England,—Long Rough Dab; Scotland,—Lang Fleuk; Ireland,—Smeareen; Holland,—Lange Schar (= Long Dab); Denmark,—Haaising (=Shark Dab); Norway,—Lerflyndre (=Clay Flounder); Sweden,—Storgapen (= Big Mouth). To our fishermen it is known as Sand Dab, Turbot, Flounder, Plaice, or Plie (to many of the French fishermen), while on the Toronto markets it is exposed for sale as Flounder or Sole. The use of all these names means that this fish is constantly confused with other kinds, for the term flounder is more often given to a very different kind of flatfish that is speared in shallow water, while a third species, that lives in deep water and cannot take the hook because of its small mouth, alone should be called sole.

We should undoubtedly use only one name for this fish and that one should be both distinctive of the kind and also quite free from objection. Since Plaice is one of the names already in use for the species and not given commonly to any other fish in our waters, it is by far the most suitable one for general adoption, particularly in the trade. To avoid any confusion with other kinds, which are given this name in other countries, it would be well to prefix the adjective Canadian, and therefore we have used the name Canadian Plaice on our title page.

RECOGNITION.

The flatfishes are all easily recognized by the long fins, one along each edge of the body, as well as by the very flat shape.

Among the flatfishes the plaice is like the halibut and unlike the flounder and its relatives in having a very large mouth with well developed teeth, the mouth indeed being so large that its angle is well back to the middle of the eye. Unlike the halibut it has along the middle of the body an almost straight 'lateral' line, which is without any arch near the head, and it differs from both the halibut and turbot in having the end of the tail rounded instead of concave or hollow. Finally the plaice differs from the window-pane, which also has a rounded tail and a large mouth, in having the eyes on the right side of the body instead of on the left side, and in not having a distinct arch in the 'lateral' line near the head. It alone of our flatfishes has these three characters combined—*large mouth, almost straight lateral line,* and *rounded tail* (see figure 2). The

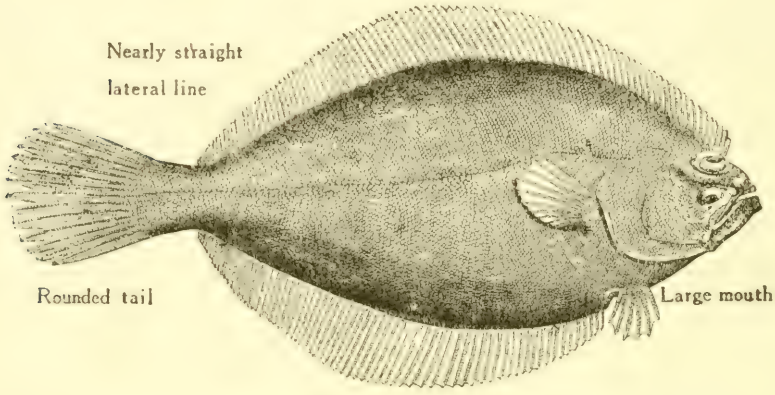

FIG. 2.—Plaice fifteen inches long from Le Have bank, off Nova Scotia. After H. L. Todd.

colour of the plaice is a uniform light or dark reddish-brown, although there is a series of from three to five dark spots along each side of the body. These are, however, usually distinct only in the young (see figure 1), but occasionally they are to be seen in quite large and old fish. Another character that is familiar to any one that handles the fish is the very distinct roughness of the surface, which is caused by the small, but sharp teeth on the free edge of each scale (see figure 11).

DISTRIBUTION.

Where does the plaice live? The answer is that it is to be found along our whole Atlantic coast and to the south along the New England states as far as Cape Cod and occasionally even off New York, while at the north it occurs as far as the strait of Belle Isle and perhaps farther, though no records of its being on the outer coast of Labrador have been published. It also lives in Greenland waters, and as a slightly different variety along the coasts of northwestern Europe.

As to the depth of the water in which it lives there are records of its having been taken in as shallow water as 5 fathoms at Iceland and in as deep water as 350 fathoms in Davis strait. Usually,

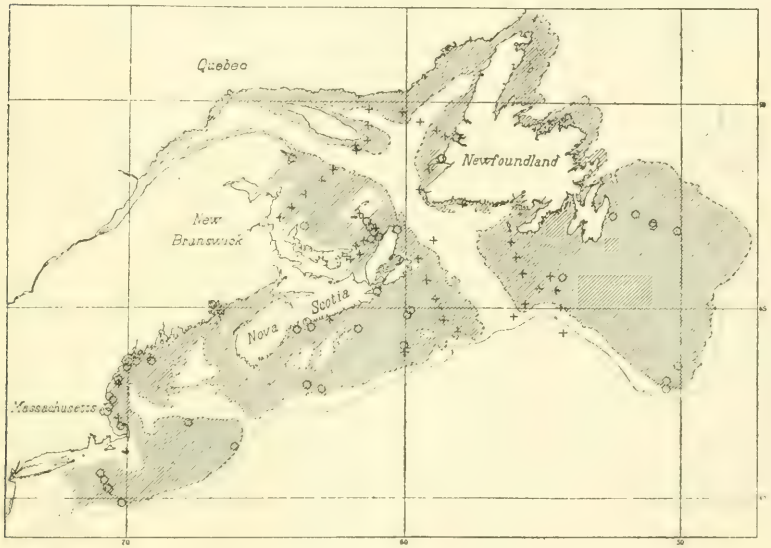

FIG. 3.—Atlantic Coast with the area inhabited by the plaice indicated by parallel lines. Circles and crosses show the places where the adults and the eggs or the fry respectively have been taken.

however, it is found only at depths of from 20 to 100 fathoms and in figure 10 can be seen how we found it strictly limited to the deeper parts of the water between Cape Breton and the Magdalen islands. At these levels is to be found during the greater part of the year the coldest part of the water, and in this it thrives.

It ranges from the deep harbours and fjords along the coast to the outer fishing banks at the edge of the continent many miles from land, in fact wherever suitable depths occur. We have shown by the lined area on the chart in figure 3 the extent of the bottom on which it lives, and it is indeed very great. The circles show where the actual captures of the fish were made, upon which we have based our chart, while the crosses give the places where the eggs or fry have been taken. The correspondence is not exact, since the latter are frequently carried by currents away from the places where the adults live.

The plaice seems to prefer to live on soft mud or fine sand, but is not strictly limited to such kinds of bottom. It perhaps moves to a slight extent toward the shore in the cold part of the year and away from it during the summer, but this movement does not seem to be very distinct.

ABUNDANCE.

Towards the north the plaice is, after the cod, the most abundant fish occurring at moderate depths and the total quantity must therefore be very great. We have made a provisional estimate of the amount available, which is based upon the quantity of cod landed yearly and the abundance of the plaice relative to the cod. They have practically the same distribution both in depth and in extent from north to south and they are taken together on the fishermen's lines. Fifteen experimental sets of the line trawl were made in the gulf of St. Lawrence at various depths and times during the summer of 1917. Many of these sets were much more favourable for taking the migratory cod than the stationary plaice, as they were made in shallow water that was only temporarily suitable for these fishes. We found the cod to be ten times as numerous as the plaice and to weigh twenty times as much. If now we take this to be the average relation between the two fishes, there must be from seven to ten million pounds of plaice thrown overboard by the fishermen each year, for from one and a half to two million hundredweight of cod are landed yearly at Canadian Atlantic ports. If the plaice were marketed at current rates for the fresh fish, it would mean for the fishermen an additional revenue of about $300,000 and the retail value would be from one-half to one million dollars yearly. This estimate is based upon definite, though

limited, information and one is certainly conservative in stating that several million pounds are lost annually, while a much larger quantity could doubtless be obtained if those spots were fished where the plaice are most abundant. In 1915 Captain Thor Iversen showed us a very large catch of plaice that had been made when trying for cod, and we have been informed by fishermen of their having made similar hauls.

CAPTURE.

The marketable fish, which are 12 inches or more in length, may be taken on the set lines or 'trawls', although they take the hook only moderately well, not being as ravenous as the cod and halibut. These 'long lines', 'trawls', or 'bultows', as they are called, consist of a heavy 'ground line' to which are attached short 'snoods' of lighter material, each with a baited hook. The whole line is stretched on bottom with an anchor of some sort at each end and one or more buoys, and is left a variable length of time before hauling. From the standpoint of the conservation of the stock of plaice this is the best method, since only the large marketable fish are caught.

They may be taken in very large numbers by the beam or otter trawl (net trawl), which is towed along the bottom, and which can be operated over a large proportion of the ground which they frequent. This method has the disadvantage of taking the small ones as well as the large, and is therefore destructive to the stock. Since the plaice is not very active, it may be taken quite easily by a small net trawl towed rather slowly, such as could be operated from a large motor boat or small fishing vessel. The capture of the small fish is to some extent prevented by the use of a net with large meshes.

DISPOSAL.

This fish has long been sold on European markets and in the large cities of the eastern United States, and quite recently it has appeared on the markets of at least one of our large cities, where it has realized from 10 to 12½ cents per pound in the fresh condition. Undoubtedly a very large quantity can be disposed of in this way, and it appears to keep fully as well as cod and haddock, judging

from the condition of fish from Chedabucto bay, Lockeport and Boston, which were sold in Toronto in the fall of 1917. We have no information as to their behaviour in cold storage after being frozen, but there is no reason for believing that they will stand it less well than those ordinarily handled by that method.

For that part of the year when they cannot be well handled in the fresh condition and for those parts of the coast that lack shipping facilities for the fresh fish trade, the curing of the fish by drying or smoking should be considered. We are informed by the Wm. Davies Co. that a demand exists for this fish filleted fresh. Each fish yields four fillets, one being cut from each side above, and one from each side below. It is fairly certain that smoked fillets of plaice would find a sale, and they would have the great advantage of keeping longer and being transported more easily than the fresh whole fish.

SIZE.

The plaice reaches a length of two feet and a weight of as much as seven pounds. Twenty-eight fish that were caught on the line trawl in the gulf of St. Lawrence off Cheticamp, C.B., in the summer of 1917, were from 13 to 24 inches in length, with an average length of 16½ inches, and from one-half to five pounds in weight, with an average weight of one and three-quarter pounds. The courtesy of Mr. Moore of the Queen St., Toronto, branch of the Wm. Davies Co. enabled me to examine seventy-seven fish, that had been sent toward the end of December, 1917, from Chedabucto bay by R. Hendsbee & Co., of Half Island Cove. These were from 12 to 20 inches long, averaging 15 inches, and from 7 oz. to 2 lbs. 10 oz. in weight, averaging 1 lb. ½ oz. Mr. Sid Perkins of the Toronto market kindly permitted me to examine twenty-four fish, said to have been sent from Lockeport, N.S., and forming the last of a shipment and therefore probably small. They were from 11½ to 22¾ inches long, averaging 14½ inches, and weighed from 7 oz. to 4 lbs., averaging 15 oz.

Although a nine-inch fish is considered marketable in Great Britain, it is probably not necessary for us to make use of fish any shorter than 12 inches, although in the bay of Fundy a lower size limit will be necessary if any number are to be taken. For that region the limit is a matter of indifference from the standpoint of

conservation, since it is not a successful spawning place and also since the growth of the fish there is very rapid. As the plaice becomes mature at a length of about six inches, a limit as low as nine inches will still leave a large number of spawning fish.

RELATION OF WEIGHT TO LENGTH.

In figure 4 is seen a curve which shows the average relation of weight to length in the plaice fresh from the water. The weight after shipment is a trifle less. To a certain extent the weight increases as the cube of the length, that is, if the length is doubled ($\times 2$), the weight is increased to eight times the former amount ($\times 2^3$). This is not, however, altogether exact, since the shape of the fish changes with age, the width increasing more rapidly than the length.

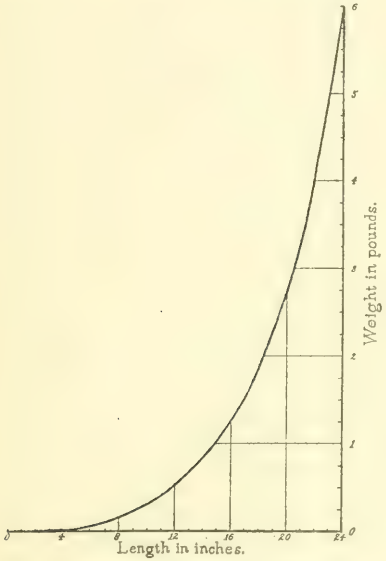

FIG. 4.—Average relation of weight to length in the plaice.

There is considerable variation in the weight of fish of the same length, as is shown by the fact that one 18 inches long, though probably weighing 1 lb. 14 oz., might weigh as much as 2 lbs. 2 oz., or as little as 1 lb. 10 oz., or even less if opened up and drained.

WASTE.

As the head is small and the guts or viscera not bulky, there is less waste in the preparation of the plaice for cooking than is the case with most fishes. Also the arrangement of the flesh is most convenient for eating, for owing to its peculiar shape there is a thick layer of flesh, entirely free from bones, on both the upper and the lower (really the right and the left) sides of the flattened backbone.

Twelve fish from 13 to 24 inches in length and from 10 oz. to 5 lbs. in weight were prepared without any attempt to retain a large proportion of the weight. The head, guts, fins, and scales were removed and the body washed. The weight after preparation amounted to about 60%, as an average value, of the weight fresh from the water, and if fish from the market had been taken, the proportion would have been still greater.

PALATABILITY.

The plaice is sweet and of fine flavour, is not oily, but rather similar to the flounder or sole, though having a distinctive texture and flavour. Although not the same, it is as nearly like the British plaice as is any fish that we have. We have eaten it at the coast and also as obtained in the Toronto markets and consider it excellent. It will undoubtedly win a place of its own on our markets, if only it be made known and a sufficiently large supply furnished to meet the demand that is created.

SEASON.

It is suitable for use throughout the year, seeing that it lives in such cold water, but it is in better condition in the fall and winter after the season's growth and before the spring spawning condition is reached. Also from the standpoint of shipping conditions the cold part of the year is preferable, but from December to April it will not be possible to obtain it in the gulf of St. Lawrence because of the ice, although to the south it will usually be possible to get it at any time of the year.

MATURITY.

We have not been able to find out as definitely as we could wish at just what size the plaice first becomes ripe, since one spawning season was over before we began this study and the next has not yet come. Fulton, and also Holt, found that the European variety becomes ripe at a length of about six inches, both males and females. Of fish taken in Passamaquoddy bay in the fall of 1917 some of both males and females were beginning to be ripe, but none shorter than five inches were becoming at all ripe. Those five inches long at that time would probably have reached a length of six inches on the arrival of the spawning season of 1918.

DIFFERENCES BETWEEN THE SEXES.

The two sexes are so much alike that an examination of the internal organs is usually necessary in order to find out whether the fish in question is male or female. One then finds, on examining large numbers of individuals, that the males do not reach so large a size as the females, for, although during the first few years of life there is not much difference between them in the rate of growth, when they become mature, the male grows more slowly than the female.

This is not the only reason for the striking lack of large males, since a study of fish of different ages shows that for the first two or three years there are more males than females, but that the older the fish become the smaller is the relative number of males, and usually females alone are found among the oldest fish. In the gulf of St. Lawrence, where there are fish of many different ages, we found the males more numerous than the females among the three-year olds, but for the later years fewer and fewer males, until finally after an age of fourteen years was reached there were only females and of these all ages up to 24 years with the single exception of the age of 21 years.

In the bay of Fundy no very old fish are found and both sexes appear to live equally long, the maximum age being ordinarily about eight years, but the same rule holds as to the young males being more numerous and the old males less numerous than the females of the same age. For example we found the proportion of the former to the latter to be for the two-year olds—38 to 22, for the three-year olds—11 to 9, for all the older fish—10 to 14. There must surely be a higher death rate among the females in early life and among the males later, and this is not influenced by the temperature, as similar proportions of the two sexes for the various years of life are found both where there is rapid growth and early maturity in warm water and also where there is slow growth and late maturity in cold water.

FERTILITY.

Like most fishes the plaice is extremely fertile and sheds many thousands of eggs during the spawning period. The actual number of eggs varies greatly, but Fulton found from 30,000 to 60,000 in

female fish weighing from two to three ounces. This quantity of eggs is produced in a single season, so that the total number spawned during the life of a fish reaching an age of fifteen or twenty years must indeed be enormous.

SPAWNING.

While spawning takes place in the spring, the exact time varies with the place, being earlier at the south than at the north—during April and May in the bay of Fundy, during May and June in the southern part of the gulf of St. Lawrence, and as late as July on the coast of Newfoundland. There is even a difference of time depending upon the depth at which the fishes live, those in shallower water spawning earlier, because the warming effect of the coming of spring reaches the bottom water earlier where the depths are slight.

There is nothing to show that the plaice gather together in particular spots to spawn, but rather that the eggs and milt are shed into the water wherever the fishes happen to be at the time. The eggs, which do not cling together but float separately, are fertilized by the entrance into each one of a minute sperm from the milt of the male. When shed they are only from one-twenty-fifth to one-twentieth of an inch in diameter, but in a short time by the entrance of a large amount of water into the space between the egg proper and the delicate covering or membrane surrounding it they become twice as large. They rise from the bottom, where they have escaped from the female fish, to the upper layers of the water where they undergo development, floating at the surface if the water is heavy or some distance below it if the surface water is light from having little salt. As they develop they become heavier and sink somewhat in the water, for in the waters between Cape Breton and the Magdalen islands we found the majority of those ready to hatch floating at a depth of about ten fathoms below the surface while the eggs recently laid were near the top of the water.

DEVELOPMENT.

When the egg, which is largely yolk, begins to develop, the living matter collects at one side and forms a little cap (see figure 5*a*), making that side heavier so that it is always underneath. The

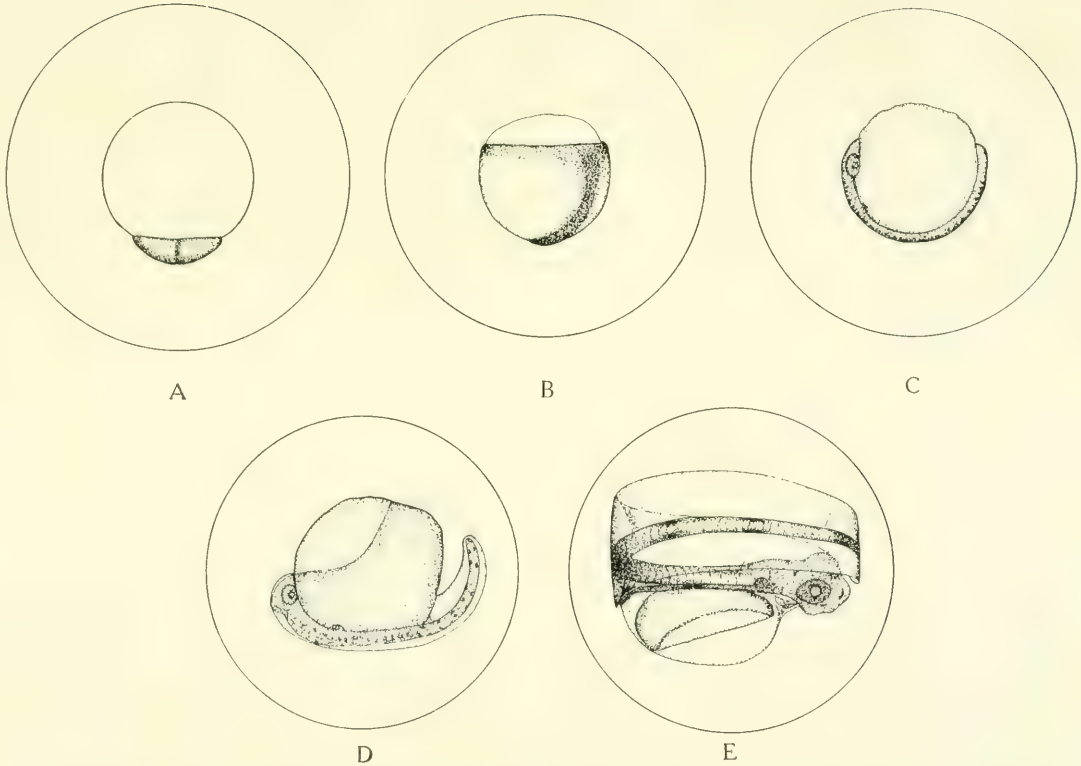

FIG. 5.—Five stages in the development of the plaice within the egg, from the first division of the living material at the lower pole of the egg (A) to the well-formed fry or larva ready to hatch and coiled up inside the egg (E). All were collected in the gulf of St. Lawrence, and are magnified 17 times.

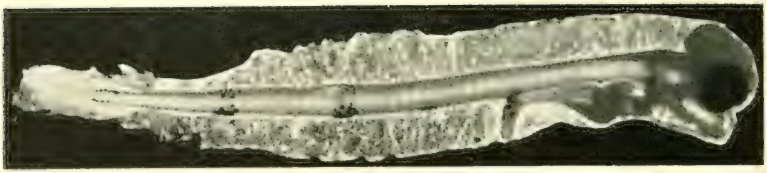

FIG. 6.—Fry one-quarter of an inch long and about three weeks old, caught in the gulf of St. Lawrence. Photographed by Professor Anderson.

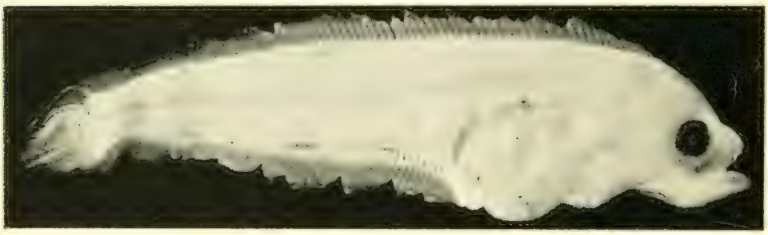

FIG. 7.—Fry eleven-twentieths of an inch long and about two and one-half months old, caught in the gulf of St. Lawrence. Photographed by Professor Anderson.

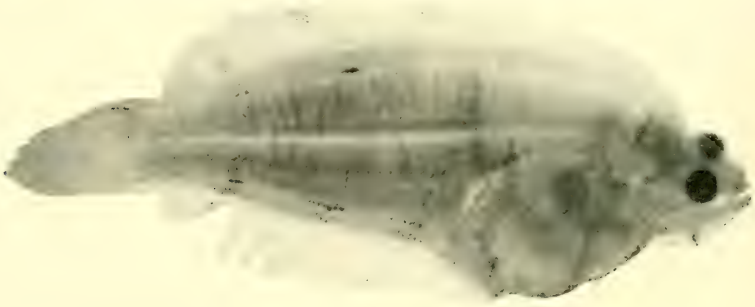

FIG. 8.—Fry seven-eighths of an inch long and about four months old, caught in the gulf of St. Lawrence. Photographed by Professor Anderson.

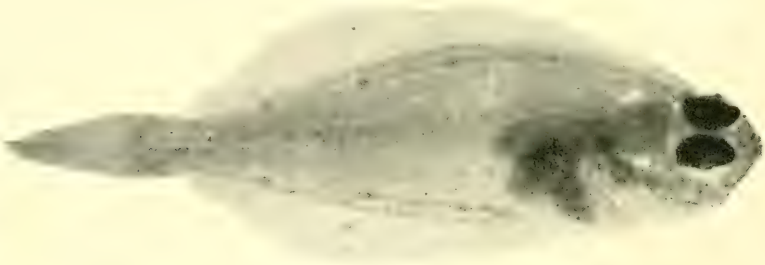

FIG. 9.—Young plaice two inches long and about eight months old, caught in the bay of Fundy. Photographed by Professor Anderson

living matter divides many times, forming a large number of living units or cells, which spread in a thin sheet over the lower surface of the egg and gradually extend upwards so as to enclose all the yolk. When this living sheet has half covered the egg, a thickening appears in it, stretching from the edge toward the centre at the lower pole of the egg (see figure 5*b*). This is the beginning of the body of the future fish and it becomes steadily longer and more distinct. One end, the head, is soon seen to be larger than the rest and in it the eyes appear very early. The smaller tail end lengthens very rapidly and grows away from the surface of the egg (see figure 5*d*). At an early stage it acquires a delicate fin membrane, which extends along the lower surface and around the tip of the tail to the upper surface, where it continues almost to the head. The colouring matter, which is chiefly black, appears throughout the body and tail in scattered branched cells, and later collects to form more or less complete bands across the tail, which are arranged in a fashion peculiar to this fish (see figure 5*e*), there being four, of which the first is incomplete above. During this growth the yolk has been used up to form the living matter and the muscles have developed on each side of the tail and body until the movements of the tail are strong enough to break the weakened egg membrane and allow the fry or larva to escape into the seawater.

By this time the mouth opening has appeared beneath the head, and, since the yolk has been used up, the larva must eat in order to keep on growing. At first it feeds upon the minute plants called diatoms, which float in the water, but as it becomes larger and more active it captures and swallows the small shrimp called copepods, that are so abundant in the water and form the 'red feed' of the herring. It has the curious habit of keeping to a depth of about ten fathoms during the day and coming to the surface only at night, probably because it is repelled by the strong light of day. The older it gets the deeper it goes into the water during the day, until finally, as we have observed in the gulf of St. Lawrence, it is far from the surface even at night. Whether this is due to the surface water becoming warmer or to the older fry preferring the deeper, colder, and darker water, we do not know.

The larva, which on hatching is only about one-fifth of an inch in length, does not grow very fast, but it soon takes on a very different shape, becoming much deeper and flattened from side to

side. Rays appear in the upper (dorsal) and lower (anal) fins as well as in the tail and paired pectoral fins, which give it a very different appearance (see figure 7). It is unlike the adult fish in having an eye on each side of the head and in swimming upright in the water instead of lying upon one side, but when it reaches a length of about one inch a part of the head twists in growing and carries the left eye across the top to the right side beside the right eye (see figure 8). This is the metamorphosis or change from the condition of the larva to that of the adult. At about this time it stops swimming freely in the water, goes to the bottom, and keeps the right side, which has the eyes, uppermost and the blind left side against the bottom. At this stage the colouring matter becomes more abundant and develops only on the right side, the left side remaining colourless. A young individual that has only recently changed from the larval condition is shown in figure 9. Figure 10

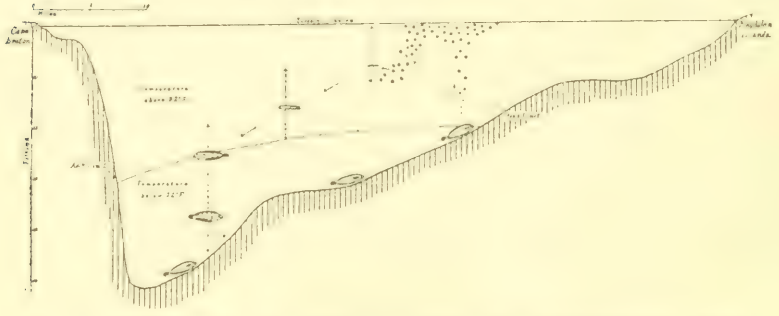

FIG. 10.—A section of the water between Cape Breton island and the Magdalen islands, showing the distribution of the adult plaice on the bottom and their life history. Arrows indicate the direction of movement or of development.

illustrates the life history of the plaice, as we have described it.

In the southern part of the gulf of St. Lawrence spawning takes place during May and June and the young fry hatch from the eggs in from two to three weeks after the latter have been shed. Their growth is very slow, amounting to only a quarter of an inch a month, so that by the end of August they are about an inch long and before winter nearly or quite two inches in length. The growth for the first year is greater in the warmer waters at the south, where a length of more than three inches may be reached before winter sets in.

BREEDING PLACES, ETC.

Although the fish do not come together to particular spots to spawn, all waters in which the adults live are not equally suitable as breeding places, for some may lack suitable conditions either for the development of the eggs or for the growth of the fry. We may say that in general the conditions are suitable, since the fry have been found, on the Newfoundland banks, on the outer banks off Nova Scotia near Sable island, along the coast of Nova Scotia, in the gulf of Maine, and at various places in the gulf of St. Lawrence (coasts of Newfoundland, Labrador, Anticosti, Gaspé, Prince Edward island, and Cape Breton island). In the bay of Fundy and in Passamaquoddy bay eggs are spawned and develop at least partially, but no fry have been found, so that the conditions there must be unsuitable, perhaps because the heavy tides prevent the warm water with small salt content, resulting from the inflow of rivers into the sea, from accumulating at the surface in the spring by keeping it mixed with the colder, salter water below. The stock of plaice in those waters must then be kept up by the older fry living in the deep water being carried in from the gulf of Maine by the deep currents and distributed over the bottom in the bay of Fundy and Passamaquoddy bay.

The eggs and fry, which float or swim more or less passively in the water, are frequently carried by the currents many miles from the places where they have been spawned, so that they are distributed far and wide. For the most part, however, the eggs, particularly the early ones, will be found near the surface just above the spots where the old fish are, and if we haul a fine net through the water at the surface at the right season of the year at any spot in the sea we can easily find out whether or not there are any plaice in the neighbourhood and how abundant they are. Their eggs may be quite readily distinguished from those of other fishes even with the naked eye by their comparatively large size and by the presence of such a large space between the egg proper and the delicate membrane outside.

The older fry keep to the deep cold water and therefore when their time of transformation comes they reach the very bottom in which the old fish live and do not live in separate regions, which might be called nurseries, such as are to be found in the case of

many other fishes. Undoubtedly some places are more suitable for them than others, but we can only state that the fish reaching the largest size are those that, as their growth in early years shows, have lived in water of intermediate temperature (about 40° F.).

The problem of the artificial hatching and rearing of this fish is not apt to arise for many years, if at all. The eggs have already been hatched in Scotland under artificial conditions and no difficulty is to be expected in that direction, but our investigations show that in nature where the conditions are suitable, as in the gulf of St. Lawrence, a large proportion at least of the eggs hatch and the fry that escape are well distributed in the water suitable for their further development and growth. It would be most difficult to distribute in so successful a manner the fry that are hatched artificially, so that it is not likely that anything would be gained by this method. As the death rate of the fry must be very high judging from our observations in the gulf of St. Lawrence, it would be of great advantage to rear them up to the time when they seek the bottom. However their delicate nature and peculiar habits make it improbable that this could be carried out successfully unless much better rearing methods are devised than those at present in use, and therefore artificial propagation of this fish must from our present knowledge be considered inadvisable.

If the plaice becomes sufficiently valuable, it may prove worth while to undertake to transplant it from overpopulated areas to those where it is rare or from which it has been fished out. This has already been done with some success in Europe in the case of certain other kinds of flatfishes, and there would be every prospect of its succeeding with our fish. The results of such transplantation should be evident in the immediate vicinity of the places stocked in this way, because the plaice moves about very little.

HABITS, FOOD, ETC.

Our fish keeps to the deep water probably to avoid the strong light of day, which so definitely affects the movements of the fry, and it does not migrate to any extent, but remains pretty much in the same place from season to season and year to year. Perhaps in the course of years it may shift a few miles, for we have found old fish that showed such growth for their early years as made it

quite certain that they had not at first lived in the exact locality where they were caught. This lack of great activity is shown also by the fact that it is not very greedy in seizing the fishermen's baits and is not very apt to be caught when many cod are about.

Its food, when it first reaches bottom, consists of the small bottom shrimp, called Amphipods and Cumacea, as well as small worms. As it grows it takes larger and larger animals as food, until finally sand dollars, sea urchins and serpent stars are the principal things to be found in its stomach, although there may be many other animals, such as various kinds of shrimp, hermit crabs, spider crabs, worms, deep sea clams, and sea squirts. Very rarely does it feed on other fish or smaller individuals of its own kind, doubtless because its feeding movements are too slow to enable it to catch any very active prey. The fact that large sand dollars and sea urchins bulk so largely in its food means that the plaice takes very little food away from our more important fishes, and it is therefore an important factor in the economy of our Atlantic waters, making available for our use food materials that otherwise would be lost. As there is usually a great abundance of food in the cold water in which it lives, there is little likelihood of its numbers being limited or its growth stunted by shortage of food.

It is preyed upon by some of the larger fishes, such as the cod, halibut, and sleeper shark, but we do not know to what extent they decrease its numbers. It is comparatively free from parasites, particularly in the colder waters. In Passamaquoddy bay and the bay of Fundy the plaice has many roundworms in the intestine and body-cavity and very often minute encapsulated distomes between the muscle fibres, whereas in the gulf of St. Lawrence both of these parasites are rare. In any event none of the parasites found would make the fish unfit for food and no diseased fish of any kind were to be found.

CLIMATE.

We may speak of the temperature, saltness, etc., as determining the climate of the water. The plaice can stand a temperature as low as any to be found in the sea, that is, about 29° F., and one as high as 50° F. as in Passamaquoddy bay, but the best temperature for its growth is about 40° F. It is probable that a higher temperature is better for the eggs and young fry. As to the saltness of

the water, it has been found in water that is quite salt, containing from 30 to 34 parts of salt per 1,000, although somewhat greater or smaller amounts are quite possible. The eggs and young fry will usually be living in water containing less salt than that in which the adults stay.

RACES.

Fishermen believe that there are different varieties of many of our species of fishes, and speak of Quoddy herring, Labrador herring, etc. Often distinct differences can be found in fish of the same kind, but from different places, one variety being deeper or thicker than another, or there being differences in colour or in average size. These characters are not very good for exact study, as they are apt to change with age or the condition of the fish. It is better to take characters that do not change with age, such as the number of rays in the fins or the number of parts in the backbone. If constant differences in these are found we may be fairly sure that distinct races exist.

The rate of growth of the plaice varies with the locality, but the chief cause of this appears to be the temperature. There are, however, other differences. The average number of rays in the longest fin (dorsal) is higher in fish from Passamaquoddy bay than in those from the gulf of St. Lawrence off Cheticamp, and in those from the Bay of Islands, Newfoundland it is still higher. There are just as distinct differences in width, although in this case the size must be taken into account. Those from the gulf of St. Lawrence are the broadest and those from the Bay of Islands the narrowest. For example the average width of plaice ten inches long would be — gulf of St. Lawrence, three and eleven-sixteenths inches; Passamaquoddy bay, three and three-eighths inches; Bay of Islands, three and one-eighth inches.

We have therefore fairly distinct races of plaice at different points along the coast, but we do not yet know how they compare with each other in quality.

LENGTH OF LIFE AND RATE OF GROWTH.

The age of a fish may usually be found by examining the scales or the small flat bones from the ears (otoliths), for rings on these indicate the seasons through which the individual has passed, just

as in the well-known case of a cut through the trunk of a tree, in which the counting of the rings gives the age of the tree in years.

In the scales shown in figure 11 it will be seen that the broad

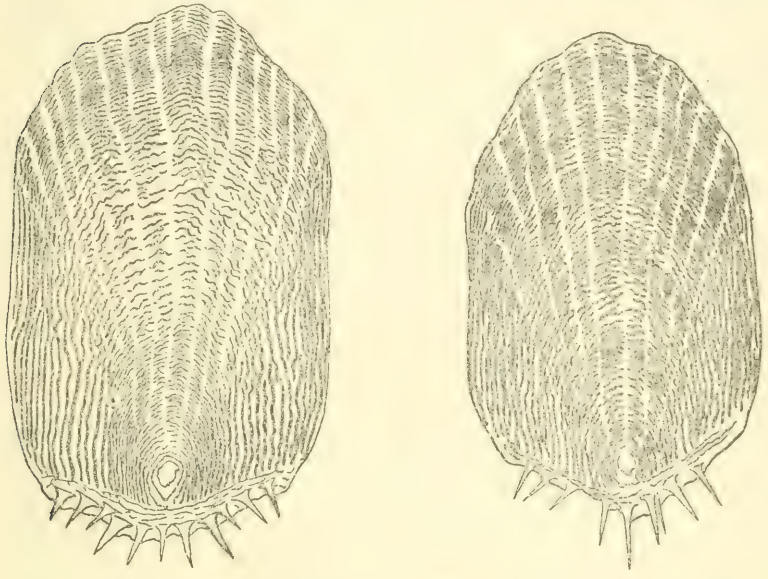

FIG 11.—Scales of two plaice of about the same length, the left of one nearly two years old from Passamaquoddy bay, the right of one more than six years old from the Bay of Islands, Newfoundland.

end of the scale is fringed with teeth, like the teeth of a comb. A short part of this end of the scale is the only part uncovered and free when the scale is still in the skin of the fish, the remainder being covered by the other scales just in front. The covered part is marked by many parallel lines, which are roughly in the shape of half circles, the centre of which is a point—the centre of growth—just inside the middle of the toothed end of the scale. The lines, which are called circuli, are partly distant from each other and partly crowded together. The plaice begins to grow in the spring at a rapid rate as soon as the water starts to warm up, and this rapid growth lasts during spring and early summer. In the part of the scale formed at this time the circuli are far apart. In late summer and in autumn the growth of the fish gradually lessens and the scale formed during this slow growth has the circuli close

together. Finally during the winter, growth of both fish and scale practically stops altogether. The edge of the scale during any winter is therefore the line where the circuli change from a closely crowded condition (autumn growth) to a widely separated condition (spring growth), and we can thus see on the scale more or less clearly the succession of spring, summer, autumn, and winter for each year of its growth.

The scale on the left of figure 11 is from a plaice seven and a half inches long, which was caught in Passamaquoddy bay, N.B., in October, 1917. It has two bands where the lines are close together, one near the centre of growth, and the other along the edge of the scale, and it has therefore lived through two autumns, the second of which is not yet over. Between these two bands is a broad area with the lines far apart. This is the growth of the second spring and summer. Where is the growth of the first spring and summer, for there must have been such, seeing that the eggs are spawned and hatched in the spring? It should be between the centre of growth and the band of the first autumn. The reason it is not there is because during the first spring and summer the fish was at first an embryo in the egg and afterwards a larva or fry. In both of these stages it is quite without scales, which begin to grow only when the left eye moves over to the right side of the head and the young fish goes to the bottom to live. This does not happen until the slow autumn growth has begun, at which time the fish is already one and a half inches long. The scales therefore show no trace of the first summer's growth and indeed some scales may not begin to grow until after the first winter.

The fish to which this left scale belongs must have been nearly two years old in the fall of 1917, which means that it was spawned in the spring of 1916. The scale on the right in figure 11 is from a fish a little under seven and one-half inches in length, which was caught in the Bay of Islands, Newfoundland in August, 1915. Although smaller than the other fish, its scale shows six bands where the lines are close together, which means that it had lived through six autumns. At the edge of the scale the lines are far apart, showing that in August, 1915, it was having its seventh spring or early summer growth, for at that latitude the summer in the deep water is very late. Although smaller than the specimen from Passamaquoddy bay, it was more than three times as old as

the latter, so remarkable is the effect of cold water as compared with warm water on the growth of this fish.

It is possible not only to tell the age of a fish from the scales, but also to calculate approximately the amount of growth in each year of its life. We first find out the correspondence in rate of growth between the scale and the whole fish by getting the average size of the scale in fish of different lengths. Then on measuring the distances between successive winter points on the scale we can calculate the amount of growth in length of the fish for corresponding years. This also gives us the length of the fish at each year of its age.

In this way we have found out that in Passamaquoddy bay with a temperature at the bottom as high as 50° F. in the late summer the plaice reaches a marketable size (12 inches) in from three to five years, in the open bay of Fundy with a temperature as high as 46° F. in from four to six years, in Chedabucto bay (temperature probably up to 38° F.) in from six to nine years, in the gulf of St. Lawrence about halfway between Cheticamp and the Magdalen islands with a temperature not above 35° F. in from eight to eleven years, and in the Bay of Islands, Newfoundland, where the temperature never seems to go above 32° F., no marketable fish were found, but the rate of growth shown by the small fish captured would mean that from 10 to 13 years would be required to produce marketable fish.

Figure 12 shows the average growth of the plaice in each of these waters, the successive years in the life of a fish being marked off at the bottom of the figure and the height to which the heavy line for each locality rises for each year showing the average length reached at that age. To what this amounts in inches is shown on the right side and in centimetres on the left. The steeper the rise in the line the more rapid is the growth. The growth is most rapid in Passamaquoddy bay, where a length of 15 inches may be reached in less than five years. The slowest growth takes place in the Bay of Islands, where the plaice are little more than five inches long at the end of the same length of time. Temperature is therefore a most important factor in the growth of these fishes.

The important thing, however, is the production of marketable fish of large size. Neither the very warm nor the very cold water are best from this standpoint, for in Passamaquoddy bay, although

the growth is very rapid, the death rate is so high that few fish reach the marketable size and in the Bay of Islands the growth is so stunted that it may be doubted whether any individuals reach any considerable size. Apparently the fish that live longest and become

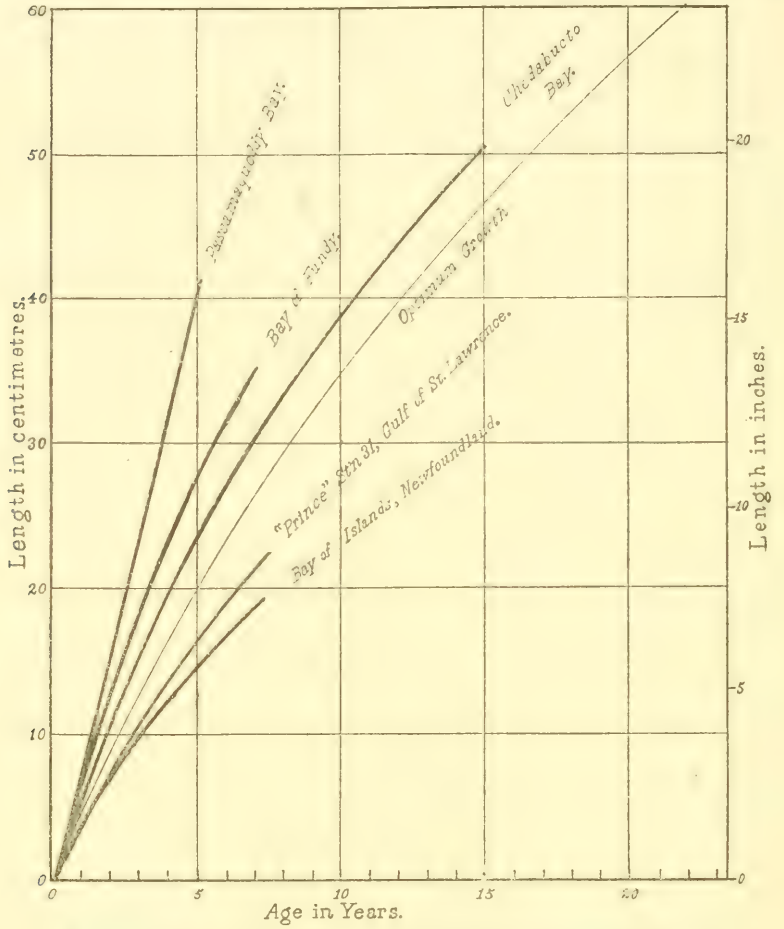

FIG. 12.—Curves illustrating the rate of growth of the plaice in different regions.

the largest are those in waters of middle warmth. We have shown this condition in the figure by the fine line which gives a growth to a length of two feet in twenty-two years. This is the 'optimum' or best growth of the plaice.

The lines in the figure give the average growth for each locality. In each place some fishes grow rapidly and some slowly, to some extent because the temperature is not the same everywhere on the bottom in each region. In Chedabucto bay it is warmer in the shallower water than in the deeper and the fish that come nearer the shore will grow more rapidly. In fact a solitary individual from this bay showed a growth nearly as rapid as that shown by those from Passamaquoddy bay. In most regions some fishes at least will be living where they have the best growth, not however in Passamaquoddy bay since owing to the heavy tides the whole body of water reaches nearly the same temperature, nor perhaps in the Bay of Islands since the sides of such a deep fjord are too steep to give suitable bottom at the depths where the temperature is best. Speaking generally the best places for the growth of this fish are the outer coast of Nova Scotia including the outer fishing banks, and parts of the gulf of St. Lawrence, and in these waters the best fishery is to be expected except where they are crowded out by other fishes.

What is the greatest age that the plaice reaches? It is certainly able to live as long as 24 years and probably 30 years should be assigned as the upper limit. Unlike man it continues to grow throughout life, the length increasing up to the time of death. There is nothing to show when the factor of old age comes in to assure death.

It is very important to know how much the fish gains in weight each year, for from the standpoint of food we are more interested in knowing how much a fish weighs than how long it is. We can readily find out the gain in weight, since we know the yearly increase in length as well as the relation between length and weight (figure 4). From these we have calculated the yearly gain in weight for the average growth in Passamaquoddy bay and in the Bay of Islands, as well as for what we have called the 'optimum' growth. Figure 13 shows the result in a graphic manner. In Passamaquoddy bay the amount gained in weight annually increases very rapidly from year to year until by the fifth year 11 ounces are gained. In the Bay of Islands the annual gain is scarcely half an ounce even by the seventh year. The 'optimum' growth shows a steady increase in the gain in weight per year, which finally amounts to as much as in the fifth year in Passamaquoddy bay and the total weight of the fish be-

comes very great. The increase in the gain, that is shown, is not quite regular especially in the later years. This is partly due to the difficulty of measuring the length of the old fish accurately enough, for a very small mistake in measurement makes a big mistake in the calculated weight. We can, however, depend upon the general

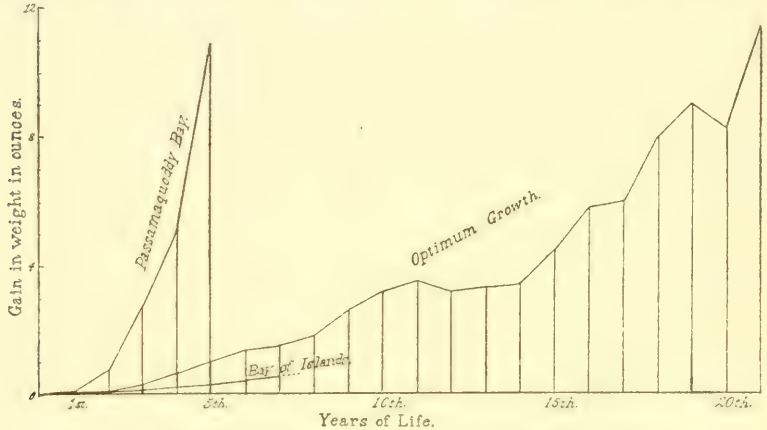

FIG. 13.—The yearly gain in weight in ounces for different regions.

increase in gain shown being substantially accurate. We may conclude that the older the plaice gets the more valuable it is as a machine for converting animals like the sand dollar and sea urchin into food suitable for man.

DEATH RATE.

During the first year while the fish is in the egg and fry stages, the death rate must be very high, so high indeed in the bay of Fundy and Passamaquoddy bay that apparently not a single egg hatches out. Because of the small number of old fish in this region very few eggs are to be found and of these none seem to reach the last stage previous to hatching. In the gulf of St. Lawrence on the other hand the conditions are more favourable and a high percentage of the eggs, which are very abundant, hatch. The fry are likewise numerous, but much less so than the eggs, there being one larva to 10 eggs, certainly no more. The older fry are still fewer in number, so that only a fraction of the young spawned each year ever change into the adult form and reach the bottom. We will consider the death rate of the adult fish in connection with our discussion of the stock.

THE STOCK.

It has been a matter of experience for a number of years that large plaice are very rare on the New Brunswick shore of the bay of Fundy. So true is this that were the net trawl not used the fish would be considered extremely rare, for it is quite the exception to take it on the line trawl. On the outer coast of Nova Scotia and in the gulf of St. Lawrence on the contrary there are many large fish and they are commonly taken on the line trawls. What is the explanation of this difference in the stock for different regions? The answer to this question is to be found in the marked difference in the death rate of the adult fish for these regions, since the rate of growth that we have found would tend to give a condition the exact opposite of what exists, namely there should be larger individuals in the warmer water.

An analysis of 66 plaice taken in one haul of the net trawl in Passamaquoddy bay on November 15th, 1917, gave the following result as to the numbers of the various ages.

Age in years.....	1	2	3	4	5	6
Number of plaice.....	1	42	19	1	3	1

We have in this case considered that the growth for the year is complete and we have given the age of the youngest as one year when in reality it was only seven months, and for the others similarly. Those in their first year were either too small to be retained in our net or they had not yet come into the bay, which explains the very small number obtained. Those in their second year were most numerous, then those in their third year. Of the later years there were very few. If the same number of young fish come into the bay each year and if conditions remain constant, the natural death rate will produce a condition in which there is a regular decrease in the number for each age, going from the youngest to the oldest. If for example 1,000 young fish settle in the bay each year, and if the death rate is one-half of the total population per year, we would have at the end of any year 1,000 fish in their first year, 500 in their second, 250 in their third, 125 in their fourth, 62 in their fifth, 31 in their sixth, and so on. Let us now suppose that a haul is made and that it takes a representative sample of 64

fish of all those more than one year old. The number of each age in such a haul would be—32 in their second year, 16 in their third, 8 in their fourth, 4 in their fifth, 2 in their sixth, and 1 in its seventh year. It is, however, quite unlikely that we would ever have such a regular result. The numbers that we actually obtained in our haul are not very different from what would be expected if the death rate of the plaice in Passamaquoddy bay were just 50% per year, as in our supposed case. In fact the numbers found indicate an even higher death rate, because there are more fish in their second year and fewer of the older fish than would be expected with such a death rate. We are quite conservative in concluding that the death rate in Passamaquoddy bay is at least 50%. We have shown this graphically on the right hand side of figure 14, where we have represented successive years by horizontal lines placed one above the other, the relative number in each year being indicated by the length of the line. The thick part of each line shows the relative number of each age actually found, while the parts between the two curved lines give the relative numbers in the stock when the death rate is 50% or one-half per year. The correspondence between the two is quite as good as could be expected. A plaice has indeed a very small chance of reaching an age greater than seven years in this bay and in fact we have up to the present found, with a single exception, none of greater age.

The stock in the gulf of St. Lawrence is quite different. 120 plaice captured in one haul of the net trawl at a depth of 30 fathoms halfway between Cheticamp and the Magdalen islands in September, 1917, were of the following ages:

Age in years	3	4	5	6	7	8	9	10	11	12	13
Number of plaice	18	9	11	7	8	4	13	11	6	9	7

Age in years	14	15	16	17	18	19	20	21	22	23	24
Number of plaice	3	1	3	3	2	1	1	0	1	1	1

Although for the many ages represented the numbers are too small to give the best picture of the conditions, it is quite clear that there is a very gradual decrease in the number with age. As the proportion of older fishes is so high, the death rate in this region

must be comparatively low. On the left hand side of figure 14 we have drawn curves to show the condition of the stock when the death rate amounts to 12½% (one-eighth) of the total population per year and we have indicated in the thick lines the numbers of each year given in the table. The agreement is close enough to warrant us in concluding that the death rate in this part of the gulf of St. Lawrence is very nearly 12½% per year, that is, only one-quarter of that in Passamaquoddy bay. It may be mentioned that in this case because the growth for the year had little more than begun we have made the ages less (by four months) than what they were, instead of greater as in the previous case. The absence of any fish under three years in age is accounted for by their very small size, due to slow growth, permitting them to escape through the meshes of the net.

We have been able to study the ages of 77 plaice from Chedabucto bay, an intermediate region, which were examined in the shop of the Wm. Davies Company of Toronto. The numbers of the various ages that were found are as follows:

Age in years	6	7	8	9	10	11	12	13	14	15	16
Number of plaice	2	12	10	10	17	4	10	4	3	4	1

In this case also we have a rather gradual decrease in numbers with age, which means a low death rate. The early years are not represented, since plaice of those ages were too small to be marketed, and if caught were not sent in. The age is given as five months greater than it actually was. The rate of decrease in numbers with age is more rapid in this region than in the gulf of St. Lawrence and less rapid than in Passamaquoddy bay, and corresponds with a death rate of about 25% (one-fourth) of the total population per year, as we have shown in the middle of figure 14. The maximum age reached in this locality (16 years) is likewise intermediate between that for Passamaquoddy bay (6 years) and that for the gulf of St. Lawrence (24 years).

Owing to the more rapid growth in the warmer water the differences in maximum size reached by the plaice in these three regions are not so great as would be expected from the differences in death rate, and are as follows—Passamaquoddy bay, 14 inches; Cheda-

bucto bay, 20 inches; gulf of St. Lawrence, 24 inches. These figures refer only to the lots that we have just considered and probably represent the average condition that would be found on examination. Occasionally one is sure to find still larger individuals. We have reached in this study the general result that in the colder water the lower death rate more than makes up for the slower

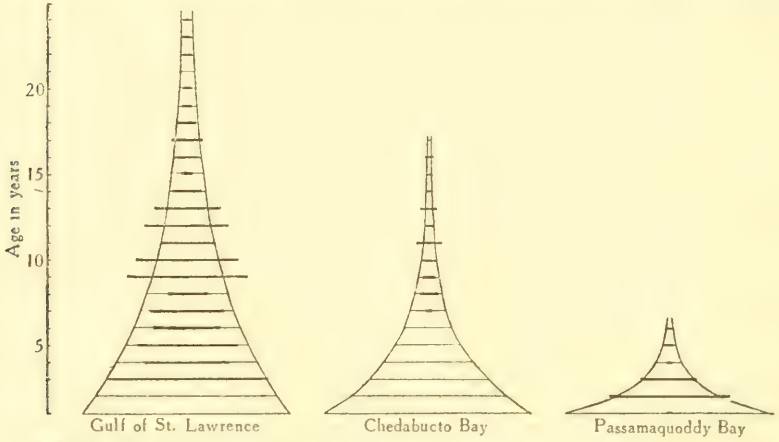

FIG. 14.—Relative numbers of the various ages in the stock of plaice in different regions.

growth in producing large individuals. As to the cause of the higher death rate in the warmer water, we can only suppose that the rapid, forced growth makes the fish, just as it makes hothouse plants, less hardy, and that they therefore succumb more readily to disease. We have already seen that they contain more parasites than the fish living in colder water.

THE EFFECT OF FISHING ON THE STOCK.

If we have a more or less stationary condition of the stock from year to year, the loss by death being made up yearly by the fish newly spawned, what will be the result of beginning to fish the area? Let us suppose that there exists a condition in which the death rate is one-seventh of the total population per year and that all fish of five years or more in age are suitable for market. In this case, which is very similar to what we have found in the gulf of St. Lawrence, the marketable stock at the end of each year will have the composition shown in figure 15 at the left ('original condition').

As before, the horizontal lines represent different ages, in this case from 5 to 21 years, and their lengths correspond to the relative abundance of the fish of those ages. It will be seen that each line is one-seventh shorter than the one immediately below.

Let us now suppose that fishing begins and that after a seventh of each age have been removed by natural means, one-quarter of the remaining marketable fish are captured by the fishermen. The removal of such a large proportion of the stock is not at all unlikely, for by two methods of calculation it was found that that proportion of the total stock in the North Sea was being removed each year by the fishermen. The effect on the stock of this intensity of fishing for one year is shown in the second part of figure 15. The numbers

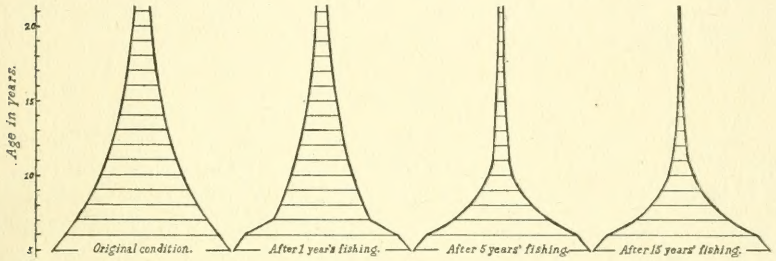

FIG. 15.—The effect of fishing on the stock.

of each age with the exception of those that have just attained the age of 5 years, have been decreased one-fourth. The conditions after fishing for 5 and 15 years respectively are also shown in the figure. The progressive decrease in numbers affects chiefly the older fish, but it entirely ceases after 17 years, by which time a new stationary condition has been reached, one characterized by very few old fish compared with the younger ones. Also we find that the average size of the fish captured becomes smaller year by year until the new stationary condition is reached. This effect is the more marked (1) the more intense the fishing, (2) the greater difference in size between the years, and (3) the greater the number of years represented among the marketable fish. Those who have fished the lobster during the last half-century can testify how definite this effect is. It is unavoidable and not due to any failure in the supply of young fish. The relative numbers of the various ages would not be changed no matter how large a number of young fish were produced, although the total quantity of fish obtained would be

greater if more young fish were spawned, that is, there will be more fish but just the same sizes as before. The only remedy is to stop fishing in whole or in part, and full recovery will be reached only after fishing has ceased for the same number of years as are represented in the stock of marketable fish. Whether such stoppage may be desirable or not, depends upon so many circumstances that it is not worth while discussing the matter here.

If a very thorough fishery for the plaice is begun, a marked decrease in the average size of the fish taken is certain to occur in the course of a few years, because the marketable fish are of so many different ages in the most important parts of our waters, and, since the plaice moves about so little, each locality will show this effect very quickly. The fishermen can easily increase their catches in such an event by seeking new grounds.

SUMMARY.

The plaice is abundant and generally distributed along our whole Atlantic coast at depths of from 20 to 100 fathoms, but may best be fished in the southern part of the gulf of St. Lawrence and on the outer coast of Nova Scotia. It is already taken in rather large numbers as a by-product in the line fishery, although not utilized, and it may easily be taken by the net trawl.

It is of good size and of fine flavour, being in the best condition and shipped most easily during the fall and winter. For years it has been sold in the markets of the American cities and is now finding a sale in Canadian cities.

The supply in our waters has as yet scarcely been touched, and it is estimated that several million pounds may be obtained yearly, but if the fishery is at all intense a certain diminution in the quantity and the average size is to be expected.

It is most desirable that this fish be handled, advertised, and sold under the name of Plaice alone, so that a permanent demand may be created for it as such. It should not be called flounder or sole, since these names are more commonly used for other fishes that differ from it in appearance and quality.

SMITHSONIAN INSTITUTION LIBRARIES
3 9088 01019 6905